Methods for the Recovery and Reuse of Waste Heat in Some Commercial Operations

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Foreword

Since 1976, numerous projects have been initiated in Alberta by industry and by academic research institutions which are aimed at better utilization of Alberta's energy resources.

These research, development and demonstration efforts were funded by the Alberta/Canada Energy Resources Research Fund (A/CERRF), which was established as a result of the 1974 agreement on oil prices between the federal government and the producing provinces.

Responsibility for applying and administering the fund rests with the A/CERRF Committee, made up of senior Alberta and federal government officials.

A/CERRF program priorities have focused on coal, energy conservation and renewable energy and conventional energy resources. Administration for the program is provided by staff within the Scientific and Engineering Services and Research Division of Alberta Energy.

In order to make research results available to industry and others who can use the information, highlights of studies are reported in a series of technology transfer booklets. For more information about other publications in the series, please refer to page nine.

Methods for the Recovery and Reuse of Waste Heat in Some Commercial Operations

In many commercial and industrial processes, heat that is produced for some purpose, or is generated by chillers and compressors, is eventually discharged into the environment through exhaust gases or effluent streams.

In commercial laundries, for example, the dirty water left from washing is still warm when it is released into the sewer. In dairies, breweries and food-processing plants, where cold storage is required, heat produced by refrigeration compressors is often dissipated into the surroundings without any attempt to recover and reuse it.

Beginning in 1985, several projects financed in part by A/CERRF were initiated to demonstrate the value of recovering waste heat or low temperature heat in various Alberta industries and businesses. Three of these projects are described here.

Heat Recovery in a Meat-Packing Plant

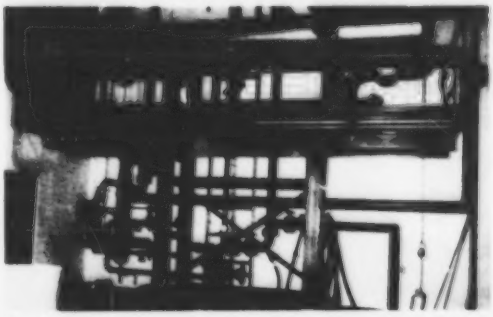
In 1985, A/CERRF and Lakeside Packers, a division of Lakeside Feeders Ltd., jointly funded the purchase and installation of a waste heat recovery system for Lakeside's cattle-slaughtering and meat-packing plant near Brooks, Alberta. The project was based on an earlier energy audit performed by the Energy Conservation Branch of Alberta Energy. It indicated that recovery of waste heat produced by the plant's refrigeration system would be cost-effective, and could result in energy savings of approximately 25 per cent.

A detailed investigation of hot water use at the plant was made by Crawford Consulting Engineering Ltd. of Calgary. The study showed that natural gas-fired steam heaters were being used to heat makeup water for process use. The temperature of the water was raised to 60°C (140°F) for one process and 82°C (180°F) for another, from an initial water temperature of 2° to 4°C (35° to 40°F) during the winter, and 21°C (70°F) in the summer. This cost approximately $75 000 a year for natural gas.

It was decided that energy and cost savings would result if a waste heat recovery system was used to preheat the relatively cool makeup water.

The system eventually designed employed a condenser to recover low-grade heat, and a desuperheater to recover higher-grade heat. These units were installed in series in the discharge line of the refrigeration compressors. A water circulation component was also included to transfer heat from the hot gas to the cold incoming water. The water circulation system includes a pump, hot water tanks and associated pipes, all with 100 per cent standby water heating and bypass piping.

Installation of the waste heat recovery system was completed in August 1986. Capital and labour costs were approximately $150 000, including $25 000 for energy monitoring equipment. The system was monitored for 10 months after it began operating.



Desuperheater (above) and condenser (below) were installed at Lakeside Packers. They allow water temperature to rise by approximately 25°C.

(Photo courtesy of Crawford Consulting Engineering Ltd.)

Results

It was expected that water temperature on the downstream side of the heat recovery system would be 46°C (115°F), but it ranged from 35°C to 38°C (95°F to 100°F). Nevertheless, this temperature was high enough to substantially reduce the need for the existing gas-fired burner. On many occasions, the burner was operated in the "night fire" mode with the main flame shut off during daytime production periods.

A comparison of natural gas bills before and after the system was installed showed that annual gas purchases should decline by approximately 9 900 to 19 000 GJ, amounting to annual cost savings of $23 000 to $31 000. Also, annual savings of about $4 700 were expected to result from lower electricity consumption by the compressors.

Installation of the waste heat recovery system allowed Lakeside Packers to avoid purchasing additional condensers for the refrigeration system. These were valued at $40 000 for a 200-tonne evaporative condenser equivalent to the condensing capacity of the new system.

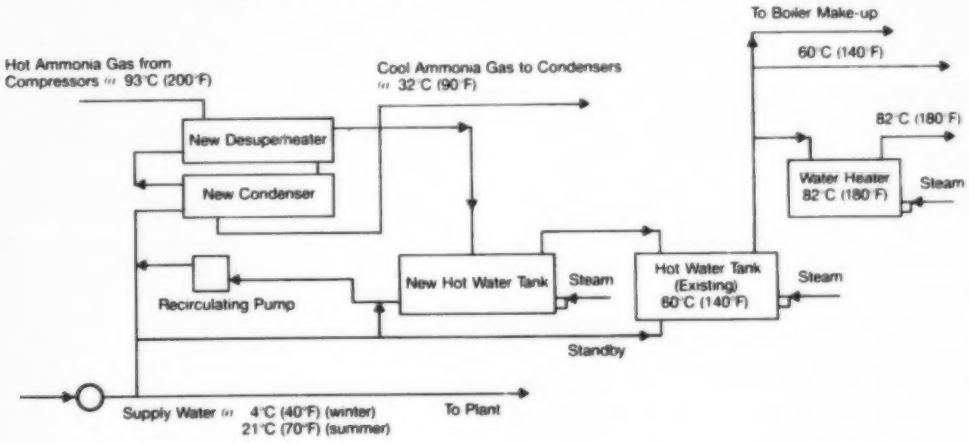
One of the peculiarities of this plant has been the number of power failures it experiences – approximately 36 each year. In the past, each power outage was followed by a production delay of up to 45 minutes while the water-heating system returned the water temperature to its normal values. With the waste heat recovery system in place, the lost time following a power failure has been usually less than 10 minutes, and at times is insignificant. Considering the fact that every half hour of lost production costs the company $1 800, it can be calculated that production time valued at $43 000 is being saved by using the waste heat recovery system.

Including the one-time saving caused by not having to purchase a new condenser, along with the value of avoided downtime, it was estimated that the first-year savings resulting from the waste heat recovery system were approximately $118 000. This amounts to a simple payback period of 15 months. In subsequent years, annual savings should be approximately $78 000.

The type of heat recovery system installed at Lakeside Packers can be used wherever commercial processes simultaneously require hot water and refrigeration, such as in dairies, breweries and food processing operations.

At other similar plants, where power failures are not a factor, annual savings of approximately $35 000 are likely. This would lead to a payback period of three to four years.

Waste Heat Recovery System Flow Diagram



(Source: *Heat Recovery in a Meat Packing Plant*, Crawford Consulting Engineering Ltd., October 1987)

Heat Recovery in a Full-Service Dairy

Concurrent with the project at Lakeside Packers, Crawford Consulting Engineering Ltd. investigated the feasibility of using a waste heat recovery system at Palm Dairies Ltd. in Calgary.

As in the Lakeside Packers' study, the consultant made a detailed study of hot water use in the plant, and then related the heat requirements to the amount of waste heat produced by the refrigeration system.

It was found that the highest grade of heat available from the compressor discharge gas, about 18 per cent of the total waste heat, was sufficient to satisfy water-heating requirements of the plant. If this heat was used instead of natural gas, the company could save approximately $15 000 a year.

A heat recovery system designed by Crawford was estimated to cost $109 000. In addition to avoiding the purchase of natural gas, it was expected the system would save approximately $5 000 a year in electricity costs because of extra condensing capacity in the heat recovery heat exchangers. Furthermore, it was estimated that some costs could be reduced because water treatment chemicals would not be consumed as quickly as in the past. Some energy savings would also result from having better controls in the compressor room. This was expected to bring the total annual savings to approximately $23 000, amounting to a simple payback period of 4.6 years.

In addition, the water-use survey revealed that existing condensers were undersized for peak summer operation, and a new 100-tonne condenser should be purchased. However, if a waste heat recovery system was installed, a new condenser would not be needed. Therefore, if the one-time avoided cost of $25 000 for a new condenser were included in the calculations, the simple payback period would be reduced to 3.6 years. This is for a demonstration project which, by necessity, includes the capital costs of monitoring equipment. If monitoring were not required, the payback period could be reduced to approximately 2 or 2.5 years.

It was also learned that lower compressor head pressures could be anticipated if the waste heat recovery system were installed. This could lead to lower maintenance costs. In turn, the lower head pressures would allow an increase in the refrigeration capacity of the compressors in the summer.

Despite the potential benefits, installation of the system was held in abeyance while negotiations were underway to sell Palm Dairies. In 1987, the company was sold, but the new owners decided that they would not proceed with the project.

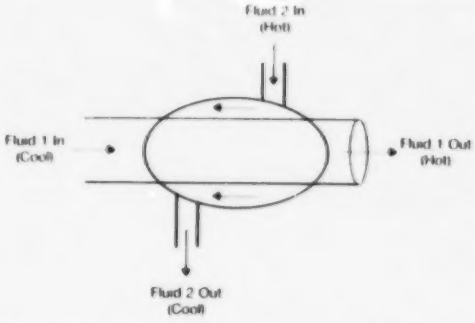
Grey Water Heat Recovery

Before 1986, approximately 171 000 litres (38 000 gallons) of hot, grey (waste) water were discharged daily from 11 industrial-sized washing machines at two commercial laundries operated by Rosedale Cleaners of Calgary. This water was dumped directly into the sewer.

In 1985, however, RTM Engineering Ltd. of Calgary was commissioned to design heat recovery systems for both laundries. Conceptually, the system designs were based on the transfer of heat from warm waste water to cold clean water by passing both streams through heat exchangers. This would allow the temperature of the incoming clean water to be raised from an initial 7°C (45°F) to approximately 63°C (145°F), only 8°C below the desired temperature of 71°C (160°F) for hot wash water. Therefore, the amount of auxiliary heat required to raise the clean water temperature by 8°C to the final temperature should be considerably less than that experienced at both plants, where gas-fired heaters were used to raise the water temperature by approximately 60°C.

While this concept formed the basis for designing the heat-recovery systems for both laundries, the engineering aspects eventually became more complicated as the project progressed. The challenge was made more difficult because very few similar projects had been attempted.

The Principles of Counter-Flow Heat Exchange



(Source: Grey Water Waste Heat Recovery in Commercial Laundries - Phase I Report, Mutual, L. and R. Goddens, RTM Engineering Ltd., February, 1986)

Industrial Plant Operations

At the Rosedale Industrial laundry, five 136 kg (300 lb.) capacity washing machines are operated four days a week to clean dirty coveralls, mop heads, mats and towels of various colours and types, including some stained with printer's ink.

Before the heat recovery system was installed, gas-fired water heaters were used to raise the temperature of fresh water to 66°C (150°F). Water at this temperature, at 7°C (45°F) and at 27°C (80°F) (called "split water"), was used in the washing machines. The resulting grey water was dumped into the sewer at the rate of 49 500 litres (11 000 gallons) a day.

Linen Plant Operations

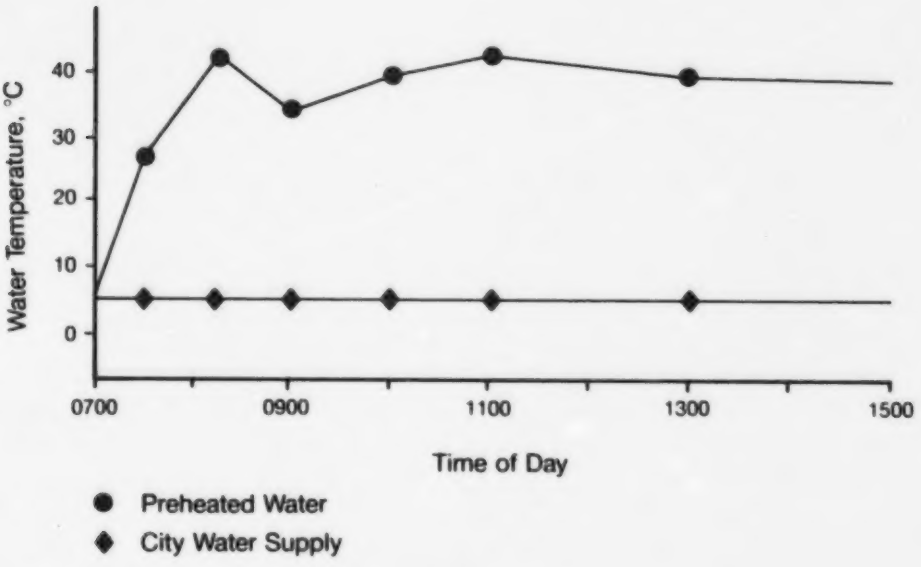
Six washing machines, operating five days a week, are used at the Rosedale Linen Plant. Before installation of the heat recovery system, water at two temperatures [74°C (165°F) and 49°C (120°F)] was used in the washing process. This produced 121 500 litres (27 000 gallons) of grey water a day. This, too, was dumped directly into the sewer.

Design Considerations

Early on, it was recognized that the foremost concern was to filter the Industrial laundry effluent to remove large pieces of lint and dirt to prevent them from entering the sewer and fouling the heat exchanger in the proposed heat recovery system. At first, settling tanks and a coarse screen were used to remove these substances, but after only one day of operation the heat exchanger became plugged. It was discovered that fine lint particles, which passed through the initial filter array, caused the problem. Consequently, it was realized that a filtering system would also be required at the Linen Plant.

The result was an overall system improvement concept that went beyond the initial objective of heat recovery to solve other problems with the two laundry operations. Some of this work, while related to heat recovery, was funded independently by Rosedale Cleaners.

Effect of Heat Exchange on Clean Water Temperature – Linen Plant



(Source: *Grey Water Waste Heat Recovery in Commercial Laundries – Phase II Report*, RTM Engineering Ltd., March 1988)

The following system components were developed, installed and commissioned at the two laundries:

(1) Rosedale Industrial
- heat recovery system
- one-machine water reuse system
- automatic self-cleaning filter system
- water treatment system

(2) Rosedale Linen
- heat recovery system
- six-machine water reuse system
- automatic self-cleaning filter system

Industrial Plant Retrofits

The basic elements of the heat recovery system at the Industrial Plant include a heat exchanger, a hot water storage tank, a hot storage sump, a lint filter, temperature controllers, pumps and water control gates.

This equipment allows waste water from the washers to be directed into either a hot sump (if the water temperature exceeds a certain set point) or a water reuse sump if the temperature is below the set point.

From the hot sump, waste water is passed through a lint filter into the hot side of the heat exchanger, and from there it discharges into the sewer. Cold, fresh water, which is preheated by passing through the cold side of the heat exchanger, is then directed into a hot water storage tank and subsequently heated in a gas-fired boiler to approximately 71°C (160°F).

Lower temperature waste water, directed to the water reuse storage tank, is subsequently used in one washing machine dedicated almost exclusively to dirty mop heads.

The wash water from one machine, used exclusively for towels stained with printer's ink and heavy grease, is not passed directly through the heat exchanger because deposits would form on the walls of the exchanger and adversely affect its performance. Consequently, this wash water is now treated with a chemical flocculant, causing the ink and grease to float to the surface, where they can be skimmed off. The remaining water is then filtered and passed through the heat exchangers.

Linen Plant

A complex heat recovery/water reuse system was designed for the Linen Plant. It recycles waste water from six washing machines and reduces water consumption by approximately 30 per cent. Depending on the temperature of the water discharged from three of the six machines, the water can be directed to the sewer, the water reuse tank or the heat recovery system. The water from two other machines is either reused or passed through the heat exchanger, while effluent from the sixth machine, which contains substances that could add unwanted colours to fabrics, is used only for heat recovery. As in the Industrial Plant, the water used for heat recovery is filtered and passed through a heat exchanger to preheat incoming fresh water.

Filter Development

While commercially available filters could have been used, their costs far exceed the available budget for this project. Consequently, an automated self-cleaning filter was designed to remove fine lint suspended in the hot, dirty wash water. It was installed at the Industrial Plant for 1/6 the cost of a commercial unit.

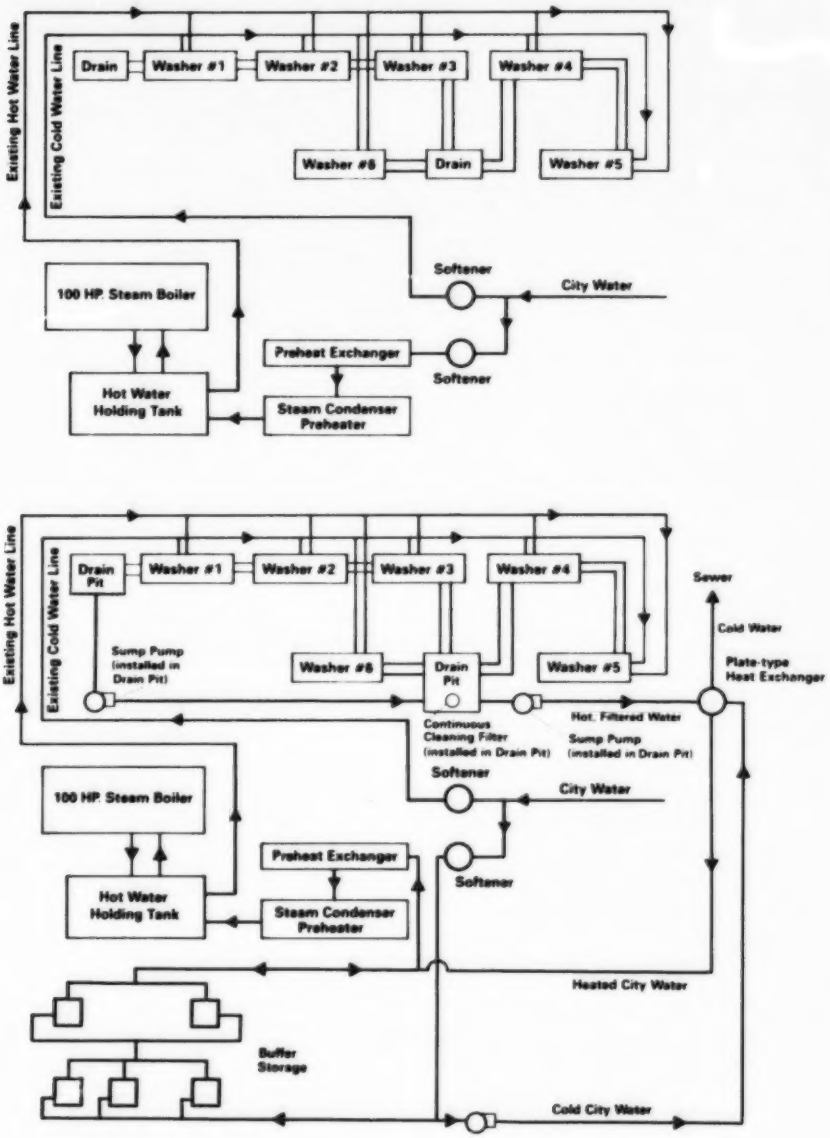
At the Linen Plant, a complication arose because of the "sizing" ingredient (polyvinyl acetate) used to provide stiffness to washed linen fabrics. Below a certain water temperature, this chemical formed a thin film on the filter screens. By experimenting with various screen mesh sizes, fouling was brought under control, but tests (outside the scope of this project) were also planned to investigate the effects of other sizing agents.

Monitoring

The systems were monitored for five weeks. Natural gas and water consumption were measured and compared with base conditions before installation of the heat recovery and water reuse system. It was found that at the Linen Plant, natural gas use declined by 38 to 50 per cent, for annual savings of $7 700 to $8 600. Water consumption was reduced by 19 to 23 per cent. This amounted to annual savings of $1 400 to $1 500, plus a reduction in sewer disposal charges of approximately $1 000 a year.

Considering the capital and engineering costs of this installation ($79 000), and the fact that the system was operating at only 66 per cent of its design capacity during the test period, a simple payback period of approximately five years was calculated for the Linen Plant.

Schematic of a Commercial Laundry Before (top) and After (bottom) Installation of a Waste Water Heat Recovery System



(Diagrams courtesy of RTM Engineering Ltd.)

At the Industrial Plant, the heat recovery/water reuse system achieved wash water temperatures that were higher and more consistent than in the past, but temperatures were not always as high as desired. Nevertheless, on the basis of test results, natural gas costs were projected to decline by $2 400 a year, a 20 per cent reduction, and savings of $1 700 a year were estimated for reduced water and sewer charges. Higher wash water temperatures were expected to result in lower soap usage, amounting to savings of $8 000 a year.

Based on capital and engineering costs of approximately $56 000, annual savings of $14 000 represent a simple payback period of approximately four years.

Conclusions

While documentation of the full magnitude of actual savings was not possible within the time limits of this project, all indications point to long-term savings in the costs of utilities and chemicals, and water and sewer charges. Furthermore, staff at both laundries have observed that wash quality has not been affected by the use of recycled water.

The experience learned from this project should result in lower engineering costs for similar installations at other locations. Subsequently, RTM Engineering Ltd. was contracted to provide engineering services for several water reuse, water treatment and waste heat reclamation projects.

RTM also calculated that approximately $800 000 could be saved annually in Alberta if grey water heat recovery systems were used in existing commercial, hospital, hotel/motel and coin-operated laundries.

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